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THE KALGOORLIE – BOULDER MINES

NOMINATION FOR AWARD AS A NATIONAL ENGINEERING LANDMARK

THE INSTITUTION OF ENGINEERS, AUSTRALIA
WESTERN AUSTRALIA DIVISION

SEPTEMBER 2001

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Prepared by The Institution of Engineers, Australia
Western Australia Division
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NOMINATION FOR AWARD AS A NATIONAL ENGINEERING LANDMARK

1. STATEMENT OF SIGNIFICANCE

Faced with the problem of how to process refractory sulpho-telluride ore in the early 1900s, Kalgoorlie mining engineers and metallurgists, and their consultants,developed new equipment and new procedures to bring about a revolution in gold extractive metallurgy. By 1905 Kalgoorlie-Boulder was recognised as the world leader in innovative gold extractive metallurgy and was second only to the South African Rand as the leading gold producing centre in the world.

The wealth and population influx generated by the Western Australian gold rushes were the most important factors in the development of Western Australia. Its Government used the security of the widespread gold discoveries to borrow money to finance an extensive programme of public works, designed to spread the benefits derived from the gold discoveries throughout all sectors of the community, and to provide an infrastructure which would help sustain the long term development of agriculture.

During the 1890s and 1900s prospecting and mining was carried out over a huge area of the state, but as the smaller outback mines were worked out or became too costly to operate, the Kalgoorlie-Boulder mines became progressively more dominant. (See Figure 1).

By 1901, a third of the Western Australia's population, nearly 65,000 people, lived on the eastern goldfields (Figure 3). More than half lived in Kalgoorlie-Boulder, and 6,313 were employed in company mines on the East Coolgardie Goldfield. The majority of newcomers had come from the eastern Australian colonies, and their presence in Western Australia had an important effect on the Federation referendum. Over half the 'Yes' votes came from the goldfields, where voting was thirteen to one in favour of Federation.

This document supports the nomination as a National Engineering Landmark of the Kalgoorlie-Boulder mines as they were developed to become the world leader in metallurgical engineering technology in the 1900s, but it should be remembered that those years were only the start of over a century of mining on the Golden Mile. The boom of the 1890s and 1900s was only the first of three, each of which made unique contributions to the Australian economy and the livelihood of its citizens. Nor should the endeavours of the miners, engineers and other technologists who sustained the industry in its lean years to secure its survival be forgotten.

2. COMMEMORATIVE PLAQUE NOMINATION

NAME OF WORK

The Kalgoorlie-Boulder Mines

PERIOD OF DEVELOPMENT

Ore processing development (1897 to 1912) within first phase of mining (1893 to 1930) (Figure 1)

PERIOD OF MINING OPERATION

From 1893 to the present day.

LOCATION

Mines on what was commonly called the Golden Mile, in the Mining Centre of Boulder, in the East Coolgardie District of the East Coolgardie Goldfield. Almost all of the mines were located within the WAGR 'Loop Line' and extended from the Adeline lease in the north to the Boulder Deep Levels leases in the south, and from Boulder Station in the west to Brown Hill Station and the Associated Northern Blocks lease in the east. (Figure 5)
In AMG coordinates from 6 596 500 N to 6 592 500 N and from 355 000 E to 358 000 E.

CURRENT LEASEHOLDER

Kalgoorlie Consolidated Gold Mines Pty Ltd [KCGM] (50% Homestake Gold of Australia Ltd and 50% Normandy Poseidon Ltd) (at 17 September 2001)

AGREEMENT TO NOMINATION

ACCESS TO SITE

There is no public access to the leases being managed as part of KCGM's 'Super Pit' mining operation, except along public roads and at the Public Viewing Platform provided by the company

FUTURE CARE AND MAINTENANCE

Kalgoorlie Consolidated Gold Mines Pty Ltd

NAME OF SPONSOR

3. INTRODUCTION: WESTERN AUSTRALIAN GOLDFIELDS

Although there had been a number of reports of gold being found in Western Australia before the 1880s these had all been associated with wishful thinking or deliberate scams. The first official report of a payable gold deposit was not made until 1885 when prospectors Charles Hall and John Slattery reported a find at what became known as Hall's Creek in the East Kimberley. The Kimberley Goldfield, the colony's first, was declared in 1886. Despite the inhospitable country and difficult access several thousand fortune-seekers joined a rush to the goldfield. Although the finds proved disappointing their real significance was that among those that the rush had attracted were experienced prospectors who had followed the finds of the 1880s in New Zealand and Queensland. These men remained in Western Australia to prospect the north-western districts and the eastern districts beyond the few pastoral stations east of Perth and the Avon valley. Prospecting in the eastern districts resulted in finds in 1887 at Eeeniun and Golden Valley, and at Southern Cross in 1888. In the same year the Yilgarn Goldfield, centred on Southern Cross, was proclaimed.

The lack of surface water supplies east of the Yilgarn deterred all but the most determined from extensive searching further east. However, Giles McPherson found gold near what was later Coolgardie in 1888, but was so ill from dehydration that he was unable to examine or peg the area. When alluvial prospects in the Yilgarn proved to be limited, most prospectors moved to the Murchison, a promising new goldfield within a settled pastoral area further north (Figure 2). By 1891, the hardier prospectors with improved experience of dry-land prospecting were returning to the eastern districts. In 1892, Arthur Bailey and William Ford followed McPherson's directions to discover a rich find at Coogardie. News of the find, which was flashed around Australia by telegraph, started Australia's most populous gold-rush of the 1890s. Coolgardie became a tent city almost overnight. For six years the 'Old Camp', as it was popularly called, was the undisputed capital of the goldfields, and the base from which rushes to new finds radiated out.

In June 1893, three prospectors, Patrick Hannan, Tom Flanagan and Dan Shea, found the first alluvial gold at Mt Charlotte, at the north end of a line of low hills 24 miles east of Coolgardie. Within a few days of Hannan registering the claim in Coolgardie, an estimated seven hundred men were prospecting the new field at 'Hannan's', or Kalgoorlie as it was later called. Among the late-comers who were forced to peg leases south of the main activity were William Brookman and Sam Pearce, representing a South Australian syndicate. Although it was several weeks before they recognized the value of dark schistose lodes, Pearce pegged many of the leases which were to become some of the most valuable mines in the world.

For subsequent details see Section 5.

4. ASSESSMENT OF ENGINEERING HERITAGE SIGNIFICANCE

4.1 Technological/Scientific Value

In 1900, the Kalgoorlie-Boulder mines were experiencing a crisis in confidence, and for the first time for ten years Western Australia's annual gold production fell (Figure 1) The extremely rich sulpho-tellurde ore found by a handful of mines, which had been preferentially mined and sent to smelters in the eastern colonies, had been worked out. On most mines the near-surface oxidised ore, which could be relatively easily treated, was also running out, and all mines were faced with the problem of how to treat the less rich sulpho-telluride ore which was amenable to neither the cyanide process nor to its alternative the chlorination process.

By 1905 there had been a transformation on the Golden Mile which had become the leading centre of gold production in the world, apart from the Rand in South Africa. Technological changes had been so remarkable that Kalgoorlie-Boulder was acknowledged as the leading centre for metallurgical innovation in the world.[1] Two successful processes had been developed for the treatment of the sulpho-telluride ore. One involved the roasting of all mined ore followed by cyanidation, and the other the roasting of concentrates and the treatment of tailings by bromocyanide. A new procedure had been adopted in both, in which all the material to be treated was finely crushed to slimes and then treated in filter presses. This all sliming process had been widely adopted on other goldfields.

New equipment, which had been developed in Kalgoorlie, was also subsequently widely used overseas. The tube mill, invented for the bromocyanide process, was the most important of these. It was further developed in the 1900s on the Rand where, in conjunction with the all sliming process, it had helped to bring about a major boost in production. The two most successful roasters which had originated in Victoria and had been further developed in Kalgoorlie, were also subsequently widely used in the USA . The filter press first used successfully in Kalgoorlie in 1897 had also been widely adopted on many fields.

A large number of rapidly implemented incremental improvements in processing was reflected in a marked increase in the patenting of improvements to equipment, including stamp mills, rock breakers, roasters, grinding pans, filter presses, vacuum filters, agitators and mixers.[2]

4.2 National and Regional Historical Significance

The wealth and population influx generated by the Western Australian gold rushes of the 1890s was the most important factor in the development of Western Australia. Prior to becoming the last Australian colony to gain responsible government in 1890, Western Australia had struggled with the British Colonial Office to gain funding for essential infrastructure such as ports, railways and telegraph lines. After 1890 the Government under John Forrest, who was Premier throughout the 1890s, used the security of the widespread gold discoveries to borrow money on the open market to finance an extensive

programme of public works. These were designed to spread the benefits of the gold discoveries throughout the different sectors of the economy - mining, agricultural, pastoral and forestry. The public works were also to lay the foundations for a greatly expanded agricultural sector and, at the same time, to channel all communications and trade through the capital, Perth.

Western Australia's increasing gold production gave the colony an international economic significance for the first time which was particularly important during 1890s when the eastern colonies were recovering from the depression which had followed the bank and property crash of 1892. In 1898, for the first time, Western Australian gold production became the highest of any Australian colony. Forty-four percent of this (0.42M ounces) came from Kalgoorlie-Boulder (Figure 1), which in the previous year (1897) had surpassed Charters Towers, Bendigo and Mount Morgan as Australia's largest gold producing centre. In 1903, when Australia had become the largest gold producing country in the world, just over half its production came from Western Australia. In that year, the state had a record output of 2.31M ounces, of which Kalgoorlie-Boulder produced 1.27M ounces, three times its output in 1898.[3]

For the first twenty years of the twentieth century Western Australia's gold exports to India provided a vital link in the financing of Britain's important trade cycle with the sub-continent.

4.3 Social Significance

The great influx of people into Western Australia during the 1890s had a major impact on a colony with such a small population (41 000 in 1885 when gold was discovered in the Kimberley). The main impact was felt after Bailey and Ford's discovery of Coolgardie in 1893 and Hannan's at Kalgoorlie in 1894.

By 1894 the colony's 1885 population had doubled and by 1898 it had doubled again. In that year Kalgoorlie-Boulder had a population of about 20,000, exceeding that of Coolgardie for the first time. In 1898, also, the colony's alluvial gold output had peaked at 75,000 ounces. Alluvial miners numbered 7000, compared with 13 000 working in company mines of whom 4 800 worked in the East Coolgardie mines.[4]

By 1901 a third of the state's population, nearly 65,000 people lived on the eastern goldfields with men outnumbering women two to one. More than half lived in Kalgoorlie-Boulder, while 6.313 were employed in company mines on the East Coolgardie Goldfield (the most ever recorded). The vast majority of newcomers came from the eastern colonies. The coincidence of the depletion of many of the Victorian mines with the depression in that state had forced many Victorian miners to move to the Western Australian goldfields. From there they sent back money to support their families until they could afford to bring them over or could obtain special loans from the Western Australian Government to finance their passages.

The presence of so many 't'othersiders' in Western Australia had an important effect on the Federation referendum in 1900 as over half the 'Yes' votes came from the goldfields where the voting was thirteen to one in favour of Federation. Other parts of the colony,

such as the metropolitan area and the northern pastoral areas, also supported Federation, and even without the goldfields the referendum might have been passed. However, the goldfields certainly played a key role, particularly in forcing the Government to call the Referendum.[5]

4.4 Rarity

Apart from the Rand mines the Golden Mile was the most productive gold mining centre in the world during the 1900s. It was also the most congested and as the treatment plants were enlarged to cater for greater tonnages and tailings dumps increased in size, it became even more so.. The proximity of the mines to each other heightened the competition between mines and the high dividends being paid ensured that cost factors were not an impediment to further treatment plant improvements.

During five years of almost continual change, most of the elements of the two suphide treatment systems were extensively modified and improved. The large number of rapidly implemented incremental improvements in processing was reflected in a marked increased in the patenting of improvements to equipment, including stamp mills, rock breakers, roasters, grinding pans, filter presses, vacuum filters, agitators and mixers. In addition to such improvements, a number of new processing units were developed (see 4.6). The most original of these was the Ridgway vacuum filter, which was invented by the chief engineer at the Great Boulder mine, George Ridgway, to replace the filter presses in which the cyanide treatment was carried out in both the sulphide processes.

With such activity taking place in ore processing the mines were ideal training grounds for young engineers and metallurgists, but as most companies only operated the one mine the only prospect which a young process engineer had of promotion was when a senior man retired. As the rate of development work slowed a steady stream of young men took their Kalgoorlie experience to gold mines in California, Mexico,and Rhodesia, to tin mines in Malaya, and zinc mines in Burma and to develop the flotation process in Broken Hill. The older men became identified with their mines and were slow to retire. Richard Hamilton, manager of Great Boulder for thirty years probably expressed a typical feeling when he wrote in 1897: 'I confess to loving the old Boulder and it is my desire to keep her ahead of all her neighbours'.[6]

4.5 Representativeness

The technological development of the Kalgoorlie-Boulder sulphide ore exploitation took place during the fifteen year period before the First World War which was unique in mining history. Not only did it see the emergence of modern mining and metallurgy but it was a period when mining was at its most international. Much of world mining finance was controlled from London; most of the leading mining engineers, metallurgists and financiers knew each other; there were very few international restrictions on mineral exploration or mining; the leading American and British mining journals reported in detail on every new mine around the globe; new techniques developed one year in Australia could be, and often were, in use in Mexico, Korea or Rhodesia the following year.

This fifteen year period was the third and most successful phase of British overseas investment in mining at the end of the nineteenth century. It had been preceded by two

phases of wasteful, inefficient speculative investment extending from 1894 to 1902, during which time the speculative end of the British investment market was largely centred on mining, and on gold mining in particular. Western Australia was only one of the targets for this activity but in the years 1895 and 1896, when it was the main target and 690 'Westralian' mining companies were floated on the London Stock Exchange, promoters' malpractice reached an all-time low. In the next phase, from 1897 to 1902, a handful of financiers who had gained control of several valuable mines on the Golden Mile manipulated their production to 'bull' and 'bear' their shares on the London market. By 1902, the main perpetrators had been bankrupted but some of the mines involved never fully recovered.[7]

4.6 Contribution to Engineering and Scientific Practice[8]

The ore processing methods and equipment developed on the Golden Mile made a significant contribution to mineral extraction technology. The 'all sliming' process which was used in both of the successful sulphide ore treatment processes, was Kalgoorlie's most important contribution. It required ore to be uniformly finely crushed and treated as one pulp instead in two parts, sands and slimes. It was initially known as the 'Australian process' but was so widely adopted in such a short time that the 'Australian' description was soon forgotten.

Several new processing units originated in Kalgoorlie. The filter press, adapted from a press used in the German sugar beet industry, was introduced in 1897 to contain slimes while gold was removed by cyanidation. It was also rapidly adopted around the world and was even used on the Rand from 1904. The Kalgoorlie processing unit which had the greatest long-term importance in ore dressing was the tube mill (or grit or flint mill) which was developed by German metallurgists for fine crushing in the Diehl sulphide treatment process. During the latter part of the 1900s it was further developed on the Rand and made an important contribution to the large increase in production there before World War One.

The use of filter presses for cyanidation was very labour intensive, and as more mines adopted the all sliming process there developed a world-wide race to develop a cheaper alternative to the filter press. George Ridgway's vacuum filter, which was developed at the Great Boulder mine, was the first (and only) automatic, continuous flow, vacuum filter to be operated successfully in the 1900s. In 1906 Ridgway filters replaced all the filter presses at Great Boulder, and within a year they were widely adopted around the world. The reason for their replacement by more conventional units within a few years was more due to the lack of after sales advice and to more active salesmanship by Ridgway's American rivals than it was to any technical shortcomings in the unit.

In their underground workings the mines on the Golden Mile used contemporary best practice, but were hampered by the small sizes of most of the leases. Because of the rivalry between the different companies, there were few amalgamations before 1910. Most underground tramway lengths, therefore, remained short, and transport predominantly manual. The small leases demanded accurate surveying, which has enabled the present-day pit workings to be developed safely using the original survey records.

4.7 Integrity and Authenticity

Today there is very little evidence on the Golden Mile of the mining and processing works of the 1900s, except where the sides of the open pit mine currently worked by KCGM has exposed the old drives and backfilled stopes. Two of the original headframes have been relocated to Hannans North Historic Mining Reserve; the one used by Great Boulder Pty at its Hamilton Shaft (1905-1969) with its contemporary timber ore bin; and the Morty headframe, used by South Kalgurli Consolidated from 1912 together with its earlier boxed sky shaft (1900). Traces of early mining activity can be found in peripheral areas to the Golden Mile (such as Hannans Lake and Brownhill). Mining related buildings from the 1900s such as the School of Mines, the Bewick Moreing & Company's offices and the London & Hamburg GR Company's office are still in use in Kalgoorlie. Kalgoorlie-Boulder contains one of the largest collection of commercial buildings from the 1900s in Australia.

4.8 Key Persons Associated with Development of the Mines

Richard Hamilton

The outstanding mine manager of his generation on the Golden Mile, Hamilton managed Great Boulder Pty, 1896-1927, developing the mine with foresight and caution. In his capacity as President of the Western Australian Chamber of Mines (1902-1940) he is generally given credit for the long periods of industrial peace on the mines.

Herbert Hoover

Partner in Bewick Moreing and Company, British mining consultants and mine managers, 1902-1908, Hoover was responsible for the management of up to twenty mines in Western Australia, including Lake View Consols, Hannans Brownhill GMC (later Brownhill Oroya) and South Kalgoorlie GM. As an independent financier, 1908-1915, he was largely responsible for amalgamating several companies to form Lake View and Star and also Oroya Links.

George Klug

One of Kalgoorlie's outstanding metallurgists, Klug designed and managed smelters at the Golden Horse-Shoe, South Fremantle and Ravensthorpe. He managed and reorganised Great Boulder Perseverance (1906) and joined Bewick Moreing & Co. in 1909, becoming its Australian manager in 1912.

George Ridgway

Chief engineer at the Great Boulder Pty mine, Ridgway was one of Kalgoorlie's most prolific inventers of ore processing equipment. He is best known for the Ridgway vacuum filter, the only automatic, continuous flow, vacuum filter in use in the 1900s

For further biographical details see Section 8.

4.9 Comparison with Other Contemporary Mining Centres[9]

In the early 1890s world gold production began a period of over twenty years of unprecedented growth, due to the development of new goldfields in the Transvaal, Western Australia and in the USA, principally in Colorado, Dakota and Montana and, later in the decade, in the Canadian Yukon. By the mid 1900s production in these countries was dominated by four districts, Witwatersrand, or the 'Rand', in the Transvaal, Kalgoorlie (officially the East Coolgardie Goldfield), Cripple Creek in Colorado and the Yukon in the Canadian North West Territory.

The Rand was by far the most important goldmining district in the world. During the Boer War years of 1900 and 1901 production had practically ceased, but by 1903 it was worth £12.64M and by 1906 it had nearly doubled to £24.76M. During the 1890s production on the Rand had been boosted by the adoption of the cyanide process for the treatment of slimes, but, during the 1900s, it was the adoption of the tube mill for the fine grinding of tailings and of the 'all sliming' process, both of which had originated in Kalgoorlie, together with the more extensive use of black miners, that had accelerated output.

Kalgoorlie and Cripple Creek, which were the only two goldfields in the world to mine sulpho-telluride ore on a large scale, were the two districts producing the next largest quantities of gold in the world. Kalgoorlie's arid surroundings of eucalypt woodland and seasonal salt lakes contrasted with Cripple Creek's location in the high mountains of Colorado. Cripple Creek's production had matured earlier than Kalgoorlie's, and by 1897, was worth £2.76M. The Colorado mines had been slow to adopt the cyanide process, and during the 1890s had used the alternative chlorination process or had railed ore to Denver for smelting. During the 1900s, cyanidation was gradually adopted and production by 1904 was worth £3.32M, which was near to the goldfield's peak annual production figure.

Kalgoorlie's Golden Mile was the most concentrated major mining district in the world. It was also the first to adopt the cyanide process for ore treatment from the outset. By 1900, when the last of the fabulously rich telluride ores were being dispatched to eastern Australia for smelting, production was worth £2.47M. When it peaked in 1903, by which time all the major mines were operating sulphide ore treatment plants, gold output was worth £4.28M and was second only to that of the Rand. In the same year, the goldfields pipeline delivered to the mines the first water from Mundaring Reservoir, in the hills near Perth, enabling the scale of mining to expand as the ore grades diminished with depth. By 1912 twice as much ore was being mined as in 1902 to produce gold worth £2.53M.

Gold on *the Yukon*, the goal of the last of the legendary nineteenth century gold rushes was predominantly alluvial, unlike the other three major districts, where reef gold was mined. Production peaked in 1900, when it was estimated to have been worth £3.60M. It was still worth £2.10M in 1904, but then rapidly diminished.

5. THE KALGOORLIE - BOULDER MINES BEFORE 1900

Hannan, Flanagan and Shea found the first recorded gold on the Kalgoorlie field in June 1893. Hannan's registration of their Reward Claim in Coolgardie on 17 June started an immediate rush to the site of their find, just west of Mount Charlotte. A few weeks later J. J. Kelly pegged a lease (known as Block 45), 4 kilometres south of the main activity, which was the first to be pegged on what was to become the Golden Mile. By the end of the year 54 leases had been pegged on the Golden Mile, though few were being worked.[10] The leases were centred on a row of wooded hills, nearly five kilometres south of Hannan's find. The most active peggers were two prospectors from South Australia, William Brookman and Sam Pearce. Pearce had a remarkable instinct for pegging prospects which became famous mines. Great Boulder was the first to be pegged, followed by a string of others, including leases which became Ivanhoe Gold Corporation, Associated Gold Mines, Lake View Consols and Golden Horse-Shoe Estates.

The Canadian, Larry Cammilleri, is credited with being the first to identify on his lease (later to become Hannans Brown Hill mine) the richness of the type of ironstone lode which was to make the Golden Mile famous.[11] However, when companies were floated in Melbourne in 1894 to work the Ivanhoe and Lake View leases, little enthusiasm was aroused. By mid-1895 only Great Boulder had done enough exploration to suggest that its ore extended to depth, but this was enough to spark off a two year promotional boom in 'Westralian' companies on the London Stock Exchange, which left all the Kalgoorlie mines with British owners.

The few, early, small stamp batteries on the Golden Mile were heavy water users as the talc-like nature of the oxidized ore tended to clog the stampers and had to washed through with a good flow of water. Extraction rates were also poor because stamped ore readily formed slimes from which gold could not be easily removed by amalgamation with mercury. Tailings, therefore, had to be ponded in dams until such a time as they could be treated effectively. At first near-surface saline aquifers associated with seasonal salt lakes were used for process water but these were rapidly depleted. In 1896 saline groundwater was discovered in some of the deeper mine shafts and was found to be more suitable for use as process water than the saltier lake aquifers.

The first important technical break-through on the Golden Mile was made in 1897 with the introduction of the filter press. Filter presses, which were introduced from Germany, were used to hold the slimes portion of crusher tailings while cyanide solution was pumped through them to remove the gold.[12] Use of the presses also permitted process water to be recycled, which together with the use of groundwater from shafts, temporarily relieved the water supply problem.

6. THE RIVAL SULPHIDE ORE TREATMENT PROCESSES

In 1897, several mines encountered very rich sulpho-telluride ores, which were not amenable to cyanide treatment because of their telluride content. Rich sulphide ores were sent to the eastern colonies for smelting, while the race was on to discover effective on-site treatment methods. Two general approaches were favoured: cyanide treatment of roasted dry-crushed ore, or the use of additional chemicals in the cyanide process. In 1899 four mines were using the former with only limited success until early in 1900 when the reconstructed plant at a small mine, Great Boulder Main Reef, began to achieve very good results. This plant became the prototype for the 'dry crush and roast' process, one of the two successful sulphide ore treatment methods.[13] The other, known as the bromocyanide, or Diehl process, had its first successful full scale trial in January 1900 at the Lake View Consols mine. This process followed more closely standard stamp mill procedures with only the concentrates being roasted, ground and cyanided, but with the sands and fines being ground to slimes and treated with bromocyanide.[14]

Both sulphide processes utilised fine crushing, sliming and filtration, a new procedure which was initially known as the 'Australian process' but it was so rapidly adopted on other goldfields that the term 'Australian' was soon dropped, and it became known simply as the all sliming process. Key elements of the two processes were derived from diverse sources. The tube mill, one of the main progenitors of many modern crushers, was introduced for sliming in the Diehl process by German metallurgists, the most successful roasters, the Edwards and Merton furnaces, came from Victoria, the use of bromocyanide from Britain, and the Wilfley concentrating table, used in the wet process, from the USA. Like most other processing equipment on the Golden Mile, these units and procedures were extensively modified and improved between 1902 and 1908.

Rivalry between the two sulphide treatment processes was intense. One measure of their comparative success was measured in terms of the unit costs of ore processing at the various mines. Successful unit cost reductions were also seen by many of the independent managers as being a means by which they could ensure that their jobs were not taken over by the firm of British consulting engineers and mine managers which was dominant in Western Australia, Bewick Moreing & Company. This company had been active in Western Australia since 1894 but it was not until Herbert Hoover became a partner in the company in December 1901, and was made responsible for the mines which the company managed, that the company began to actively promote its management role.[15]

The British companies which owned the majority of large mines in Western Australia after 1900 began to realise that the days of making money by the financial manipulation of their companies stocks were over and that money now had to be made by mining gold efficiently. Hoover grasped the opportunity by instituting a common accounting system for all the mines Bewick Moreing managed and publishing monthly unit costs for each mine (whenever they were good). The contrast to the pre1900 accounting secrecy was dramatic and Bewick Moreing rapidly gained a reputation for competent, open, management. The directors of British companies in difficulties soon began to knock on the company's door to seek help, particularly after vigorous action by Hoover's men had returned several companies to profitability. The independent managers soon realised the danger they were in and adopted similar procedures as Bewick Moreing with dramatic results. By

1905, it was the independent managers, like Nicholson at the Ivanhoe, and Hamilton at Great Boulder, who were leading the world's unit costs ratings.

The battle of the sulphide plants was also over by 1906. The dry crush and roast process was now consistently, if only marginally, cheaper than the Diehl, or bromocyanide, process.[16] Now the companies became more preoccupied with increasing the capacities of their processing plants to cater for the much larger tonnage of ore being mined in order to maintain profit levels as the grade of ore diminished with depth

7. STEAM POWER AND WOOD FUEL

During the 1900s Kalgorlie-Boulder had the largest concentration of stationary steam engines in Australia. Large tandem compound steam engines were then in their final stage of development and these were used by most mines on the Golden Mile as winder engines and mill engines. The first reliable steam powered air compressors were also produced in the 1900s and horizontal cross compound compressors were used for powering rock drills at all the major mines. Large internal combustion engines proved unreliable for the heavy duty use required by the mines, although small kerosene powered engines were used in the early days for powering machinery such as pumps in locations where long steam lines were uneconomic. These were soon superseded by electrically powered equipment.

Two of the large mines generated their own electricity for lighting and operating electrified plant, but the majority received electricity from Kalgoorlie Electric Power and Lighting Corporation (KEPLC), a private company whose generating station was largest in the state (4 MW in 1914) until the opening of the Government's East Perth Power Station in 1918. In addition to servicing the mines it also provided power to the Kalgoorlie Electric Tramways Co. and lighting for the Kalgoorlie Road Board.[17]

Initially the mines used coal from Newcastle (NSW) or Collie (WA) as their main fuel but once their boilers had been adapted for firing by eucalypt wood, local timber became by far the cheapest and most effective fuel in the goldfields region. In the early days, the Kalgoorlie mines employed contractors to cut firewood and deliver it to the mines or sidings along the Perth to Kalgoorlie railway. By 1900, all timber within carting distance of Kalgoorlie and of the sidings had been cut out. A number of firewood supply companies were then formed to organise woodcutters camps in the bush and to carry firewood to Kalgoorlie by narrow gauge railways ('woodlines').

The largest woodline company which supplied a large proportion of the mines and also the KEPLC power station, the W.A. Goldfields Firewood Supply, operated from Kurrawang, just west of Kalgoorlie, cutting a large area to the north of the Perth-Kalgoorlie railway until 1921, when its operations were relocated further south. Two other woodline companies, which also supplied the mines, cut areas south and east of Kalgoorlie.[18]

The heaviest timber usage occurred in the years from 1904 to 1914, when large tonnages of ore were being mined and most mines were roasting all their mined ore using firewood fuel. During that time, quantities used per year were probably between 400,000 and 600,000 tonnes. In the woodland cut for the Kalgoorlie mines, yields per hectare of from seven to nine tonnes of firewood and mining structural timber were obtained, resulting in an area of over 60,000 hectares being cut over each year (without allowing for the large areas covered by salt lakes). All the other mining centres on the goldfields also used firewood fuel. It has been estimated that during the twentieth century a total of about 25 to 30 million tonnes of timber were cut on the goldfields from an area of up to 4 million hectares.[19] This is equivalent to the area of English forest used by all the medieval and Elizabethan iron masters and shipwrights. However, unlike the English forests, the woodlands of the goldfields (or, at least, those south of Menzies) have been allowed to regenerate, and natural regrowth is now extensive.

8. MANAGERS AND INVENTORS

Richard Hamilton (1855-1943)
One of the outstanding Australian mine managers of his generation, Hamilton managed Great Boulder Pty, 1896-1926, and was President of the Western Australian Chamber of Mines, 1902-1940, in which capacity he was credited with the long periods of industrial peace on the Golden Mile. Hamilton was educated at the Bendigo School of Mines and managed mines in New South Wales, Kolar (India) and Arizona before being invited by Zebina Lane to manage Great Boulder. He developed the mine, which was the market leader during the 1890s, with foresight and caution, maintaining a stockpile of bullion to even out production variations. He was an early advocate of the Edwards roaster, which was later universally adopted. When trials of the radical Ridgway vacuum filter proved successful he replaced the mine's filter presses with vacuum filters (though their use was later modified due to unpredictable circumstances). During the 1920s to keep down costs he reluctantly allowed a large part of Great Boulder to be worked by tributors, but their use allowed his mine to survive. In the 1930s, he attempted to collaborate with de Bernales when the latter gained control of Great Boulder, but eventually retired to his farm near Moora.

Herbert Hoover (1874-1964)
Hoover was educated at Stanford University, California, and was employed by the British mining consultants, Bewick Moreing & Co., on the recommendation of Louis Janin, a Californian consulting engineer. He arrived in Coolgardie in May 1897 and, after a brief time at the Hannans Brownhill mine in Kalgoorlie, worked as an inspector of mining prospects. He was manager of one of the mines which he had recommended, the Sons of Gwalia mine at Leonora, from April 1898 to March 1899. After working in China for two years for Bewick Moreing, in December 1901 he became partner in the company with special responsibility for operating all mines managed by the company. He was very successful in extending the company's business in Western Australia, where by the end of 1903, the company managed twenty mines, including Lake View Consols, Hannans Brownhill, and South Kalgoorlie. He had an important influence on the development of the mines on the Golden Mile, particularly in the drive to reduce costs. In 1904, Bewick Moreing's expansion ceased due to the company's failure to take over management of two very rich Kalgoorlie mines, Great Boulder Perseverance and Golden Horse-shoe Estates. Hoover visited the state in 1902, 1903, 1905 and 1907. After 1905 he took a leading part in financing and managing the development of the flotation process at Broken Hill to extract zinc from tailings dumps. He left Bewick Moreing in July 1908, selling his partnership to another American, W.J. Loring. Hoover then built up a very profitable business as a leading London mining consultant and financier. He sold all his business interests in 1915 and managed international war relief in Europe for the rest of the war. On his return to the USA he entered politics as a Republican.

Charles Kaufman (1847-1912)
In the late 1890s, the controversial American engineer was representative on the goldfields of, first, Whitaker Wright, and then, Horatio Bottomley, the two notorious, London-based, financiers. He himself gained control of the Golden Horse-shoe mine in 1898. He lost heavily during the collapse of Bottomley's companies in 1899, but remained on the board of the Golden Horse-shoe and had an important influence on its operations. He was ahead of his time in advancing a number of technical innovations, particularly in smelting. He was behind the Golden Horse-shoe's gold

smelter (the only one ever built in Kalgoorlie), the Fremantle smelter (later converted to smelt lead from Northampton mines acquired by him) and the Ravensthorpe copper smelter. His attempts to diversify into base metal mining were failures due to the limited reserves of his mines. He maintained a firm control over the speculative elements on the board of the Golden Horse-shoe, but after his death in 1912 they resurfaced to the detriment of the company and its mine.

George Klug (1875-1935)
One of Kalgoorlie's most able metallurgists and managers and, after the First World War, a highly regarded leader of the Australian mining industry, Klug was born in Melbourne and studied at the South Australian School of Mines. He worked initially for the State Government Analyst in Adelaide, and in 1896, joined BHP at Broken Hill as its chief chemist, and later worked as its assistant metallurgist. In 1900 he moved to Kalgoorlie as chief metallurgist to the Golden Horse-shoe mine, under manager John Sutherland, another former Broken Hill metallurgist. To process high grade sulpho-telluride ore, Sutherland and Klug built a small smelting works at the mine. In 1901, Klug took over the management of a smelter operated by Fremantle Smelting Works, another of Kaufman's companies. When the smelter's costs escalated due to technical problems, it was closed down in July 1902. After several months as manager of the Golden Horsehoe mine, in Sutherland's absence overseas, Klug returned to Melbourne, but was recalled to become manager of another smelter company formed by Kaufman, for which Klug designed and built a new smelter at Fremantle. In December 1904, after the manager of Great Boulder Perseverance was involved in a dispute over reserve estimates, Klug was invited to take over its management. His work in reorganising underground development, and in starting preventative maintenance of the treatment plant, was widely praised. He also rebuilt the roasters to his own design. In August 1906, he became manager of Mount Cattlin Copper Company, a company acquired by Kaufman to operate a new smelter at Ravensthorpe, for which Klug had been consulting engineer. He left Ravensthorpe in December 1908 to join Bewick Moreing & Co. as manager of the Great Fingall Consolidated mine at Day Dawn, in the Murchison. Due to illness in his family, Klug was transferred to Bewick Moreing's Melbourne office in August 1910. In July 1912, he became general manager in Australasia for that company, which in addition to gold mining was then engaged in the development of the flotation process at Broken Hill and in the revival of Queensland copper mining. Klug remained with Bewick Moreing until his death in 1935 and was associated with the establishment of the Zinc Corporation, the Electrolytic Zinc Corporation, and Gold Mines of Australia.

George Ridgway (b. 1867)
Ridgway served an engineering apprenticeship and attended South Kensington Technical School before migrating to Melbourne in 1888. He worked as engineer and manager for two brick-making companies and in 1894 came to the WA goldfields where he operated a condensing plant at Black Flag. With his brother, he ran a brickworks at Midland Junction for two years, before returning to the goldfields to join the engineering staff of the Lake View South mine. He worked on the erection of Great Boulder's sulphide plant and was the mine's chief engineer from 1900 to 1903. He was manager of the Princess Royal mine at Norseman until 1905 when he returned to Great Boulder as assistant manager and chief engineer. He had already applied for three metallurgical patents when, in July 1903, he made his first application for a patent for a 'rotary slimes filter'. By January 1906, a prototype of the first continuous flow automatic vacuum filter was in operation at Great Boulder. After a year's successful trial, a further ten units were ordered to replace all the company's filter presses. Ridgway's vacuum filter was unlike any previous filtering device. The low

cost and high extraction rate attracted much favourable publicity. The unit was manufactured under licence in the UK and by the end of 1907 was in use on a number of newly established goldmines around the world, particularly in Mexico. However, because of its sophistication, the unit was not suitable for use without technical assistance being provided to set it up and within two years most units had been replaced by more conventional units. At Great Boulder graphite impregnation of the ore drew attention to the shortcomings of the unit's continuous flow system which had to be replaced by batch treatment. Ridgway invented two other larger capacity, batch fed, vacuum filters both of which operated successfully. One, which was installed at a Bullfinch mine in 1915, had the greatest potential but the mine was only a short term one, and no opportunity arose to develop the unit further. Ridgway was a prolific inventor. Between 1903 and 1911 he applied for nine different metallurgical patents. He was a partner of Richard Hamilton in reopening the Lancefield gold mine near Laverton in 1915.

9. KALGOORLIE – BOULDER MINING TODAY

The area known as the Golden Mile is now operated by Kalgoorlie Consolidated Gold Mines as Australia's largest open pit gold mine, commonly known as the Super Pit. When fully developed the pit is expected to be 4 km long, 1.5 km wide and 650m deep. The pit is estimated to have a remaining life of about 14 years (from March 2001) but potential exists for 'a significant increase in mine life', possibly including underground operations.

In the year ending 30 June 2000, 0.67 million ounces of gold was produced from the Super Pit, which is about half the maximum quantity produced by all the Kalgoorlie mines in their peak year of the 1900s (1903, see Figure 1). To produce the 1903 figure of 1.27 million ounces, 0.983 million tonnes of ore had to be mined. By comparison in year 1999-2000 to produce half the 1903 quantity of gold 10.20 million tons of ore had to be mined, over ten times the 1903 quantity.

10. REFERENCES

Allen, R., *West Australian Metallurgical Practice,* Kalgoorlie, 1906.

Appleyard, R.T., 'Western Australia: Economic and Demographic Growth, 1850-1914' in C.T. Stannage (ed.), *A New History of Western Australia,* Perth, 1981.

Appleyard, R.T. and M. Davies, 'Financiers of Western Australia's Goldfields' in R.T. Appleyard and C.B. Schedvin (eds), *Australian Financiers: Biographical Essays,* Melbourne, 1985.

Bertola, P., 'Kalgoorlie, Gold, and the World Economy, 1893-1972', Curtin University of Technology PhD thesis, 1993.

Blainey, Geoffrey, *The Rush that Never Ended: A History of Australian Mining,* Melbourne, 1963; third ed., 1978.

Blainey, Geoffrey, *The Golden Mile,* St Leonards, NSW, 1993.

Cammilleri, F., *Chasing the Weight 1886-1912,* Perth, 1986.

Casey, G. and T. Mayman, *The Mile that Midas Touched: The Story of Kalgoorlie from 1893 to 1968,* Adelaide, second ed., 1989.

Charleton, A.G., *Gold Mining and Milling in Western Australia with Notes upon Telluride Treatment, Costs, and Mining Practice in Other Fields,* London, 1903.

Chippendale, G.M., *Eucalypts of the Western Australian Goldfields (and the Adjacent Wheatbelt),* Canberra, 1973.

Clark, D., *Australian Mining and Metallurgy,* Melbourne, 1904.

Cleland, E.D., *West Australian Mining Practice,* Kalgoorlie, 1911.

Crowley, F.K., *Australia's Western Third: A History of Western Australia,* Melbourne, 1970.

Curle, J.H., *The Gold Mines of the World, containing Concise and Practical Advice for Investors gathered from a Personal Inspection of the Mines,* London, 1899.

de Launay, L., *The World's Gold,* translated by O.C. Williams, London, 1908.

Eissler, M., *The Metallurgy of Gold: A Practical Treatise,* London, fifth ed., 1900

Gunzburg, Adrian and Austin, Geoff, *Rails through the Bush: Timber and Firewood Tramways and Railway Contractors of Western Australia,* Melbourne, 1997.

Hartley, R.G., *Industry and Infrastructure in Western Australia 1829-1940,* West Perth, 1995.

Hartley, R.G. 'A History of Technological Change in Kalgoorlie Gold Metallurgy 1895-1915', Murdoch University PhD thesis, 1998.

Nash, G.H., *The Life of Herbert Hoover: The Engineer 1874-1917,* New York, 1983.

Porter, A., 'Richard Hamilton, 1855–1943, and the Great Boulder Mine in Western Australia, 1896 to 1927', BA Honours thesis, Murdoch University, 1981.

Quartermaine, M.K. et al., *Technological Survey of the Golden Mile: A Visual Record of the Machinery, Structures and Equipment used on the Golden Mile, Kalgoorlie from 1893,* Kalgoorlie/Perth, 1981.

Richardson, P., 'Collins House Financiers: W.L. Baillieu, Lionel Robinson and Francis Govett' in R.T. Appleyard and C.B. Schedwin (eds), *Australian Financiers: Biographical Essays,* Melbourne, 1985.

Truscott, S.J., *A Textbook on Ore Dressing,* London, 1923.

Webb, M. and Webb, A., *Golden Destiny: The Centenary History of Kalgoorlie-Boulder and the Eastern Goldfields of Western Australia,* Kalgoorlie-Boulder, 1993.

10. END NOTES

[1] A. James, 'Progress in Gold-ore Treatment during 1906', *Engineering and Mining Journal,* 5 January 1907, pp.17-20.

[2] R.G. Hartley, 'A History of Technological Change in Kalgoorlie Gold Metallurgy 1895-1915', Murdoch University PhD thesis, 1998, Chapter 7, 'Mining and Metallurgical Patents'.

[3] L. de Launay, *The World's Gold,* translated by O.C. Williams, London, 1908, pp.105-123.

[4] P. Bertola, 'Kalgoorlie, Gold and the World Economy. 1893-1972', Curtin University of Technology PhD thesis, 1993, Table 1.2.

[5] F.K. Crowley, *Australia's Western Third: A History of Western Australia,* Melbourne, 1970, pp.152-53.

[6] R. Hamilton Letterbook 1, 22 July 1897, held by the Hamilton family.

[7] R.T. Appleyard and M. Davies, 'Financiers of Western Australia's Goldfields'in R.T. Appleyard and C.B. Schedvin (eds), *Australian Financiers: Biographical Essays,* Melbourne, 1985; J.W. McCarty, 'British Investment in Western Australian Gold Mining, 1894-1914', *University Studies in History,* 4 (1962), pp.7-23.

[8] Hartley, *op. cit.,*Chapters 2-6.

[9] de Launay, *op. cit.,* pp.102-27.

[10] Leases listed in Dept of Lands & Surveys 1893 field book. Copy held by KCGM.

[11] F. Cammilleri, *Chasing the Weight,* Perth, 1986, pp.42-43.

[12] W. McNeill, 'Filter-Press Treatment of Gold Slimes (Hannan's, West Australia)', *Trans. Institution of Mining and Metallurgy* 6, 1897-98, pp.247-69.

[13] J.T. Marriner, 'Roasting and Filter-Press', *Engineering and Mining Journal,* 5 September 1903, pp.352-53.

[14] H. Knutsen, 'The "Diehl" Process', *Trans. Institution of Mining and Metallurgy,* 12, 1902-03, pp.2-36.

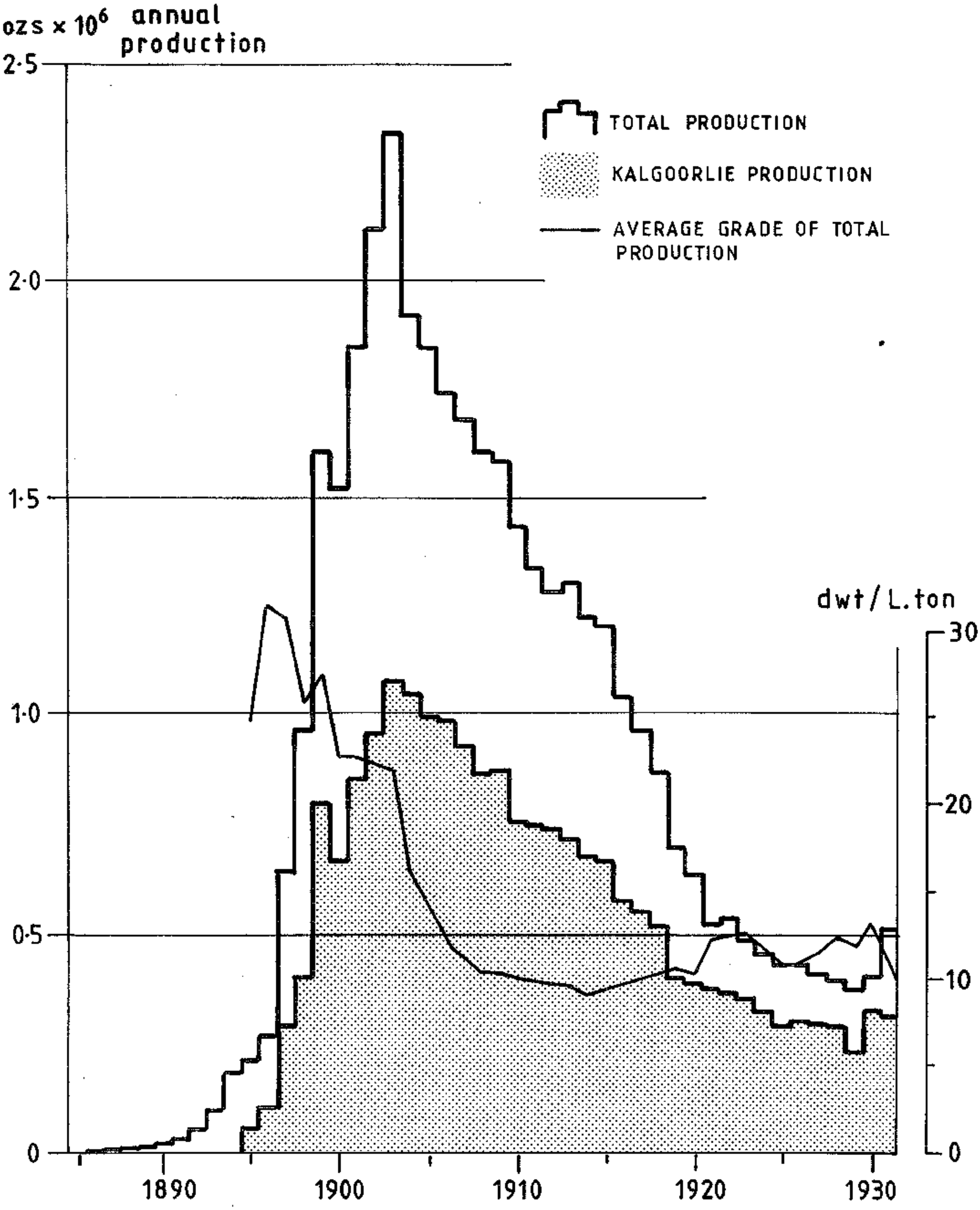
[15] George H. Nash, *The Life of Herbert Hoover: The Engineer, 1874-1914,* New York, 1983, pp.223-93.

[16] A. James, *op. cit.,* pp.19-20.

[17] J. De Burgh, 'The Development of a State Government Electricity and Gas Supply in Western Australia', unpublished manuscript, 1958,copy held by Battye Library, pp.97-128.

[18] A. Gunzburg and G. Austin, *Rails through the Bush: Timber and Firewood Tramways and Railway Contractors of Western Australia,* Melbourne, 1997, pp.160-89.

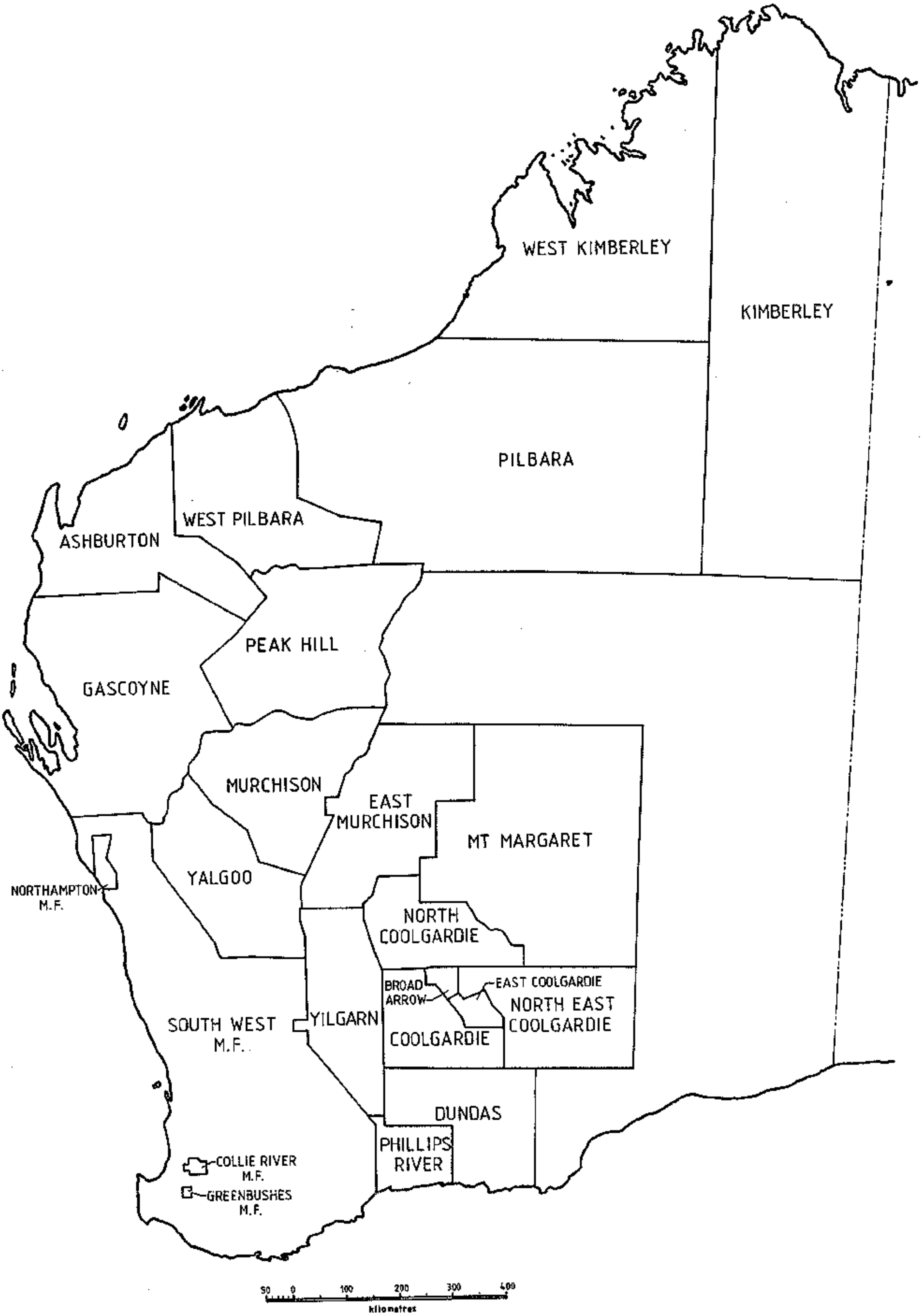
[19] G.M. Chippendale, *Eucalypts of the Western Australian Goldfields (and the Adjacent Wheatbelt),* Canberra, 1973, pp.8-10.



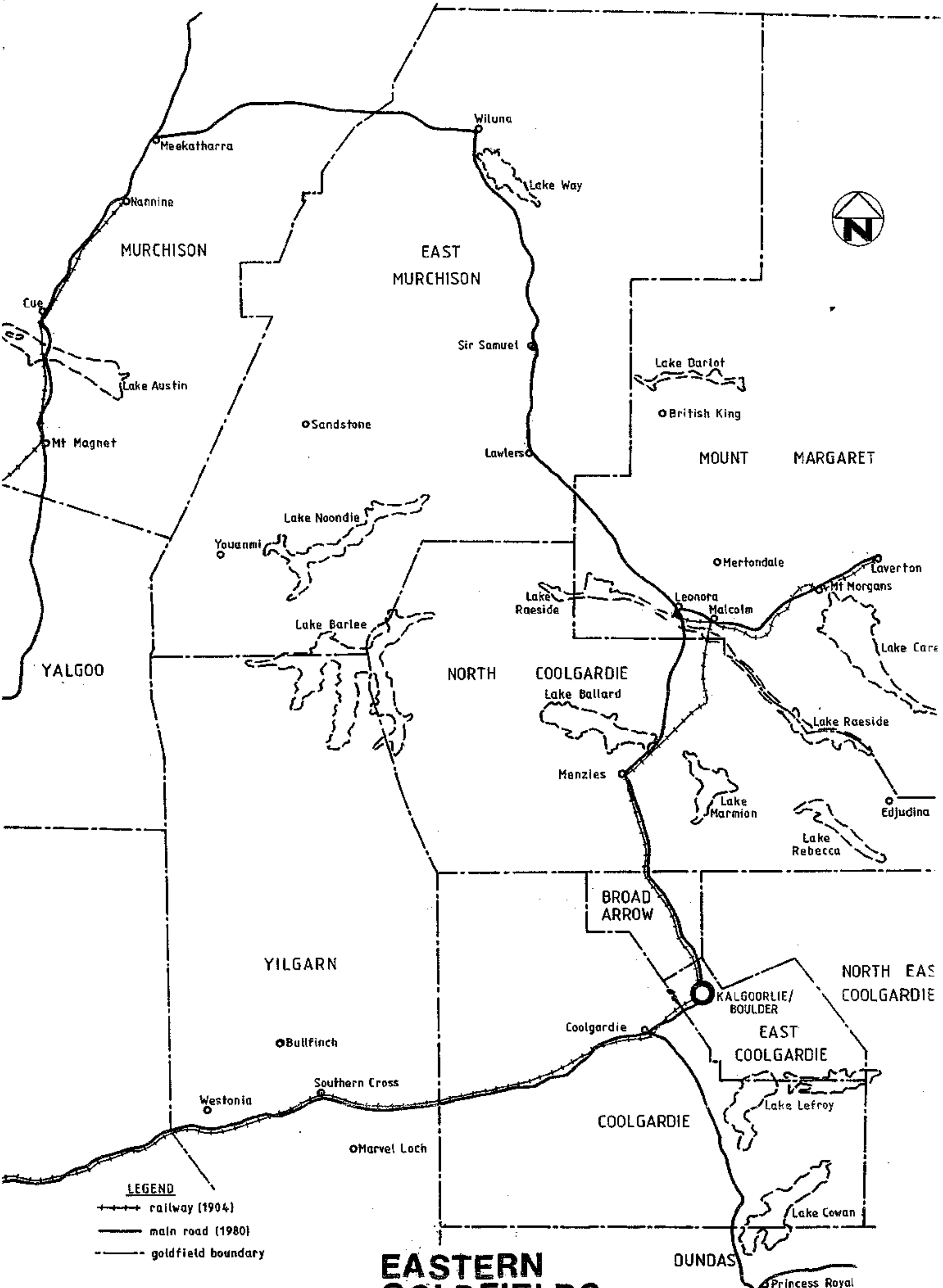
source: Woodall & Travis p.58

UNITS FOR QUANTITIES: GOLD IN FINE OUNCES.
ORE IN LONG (IMPERIAL) TONS.

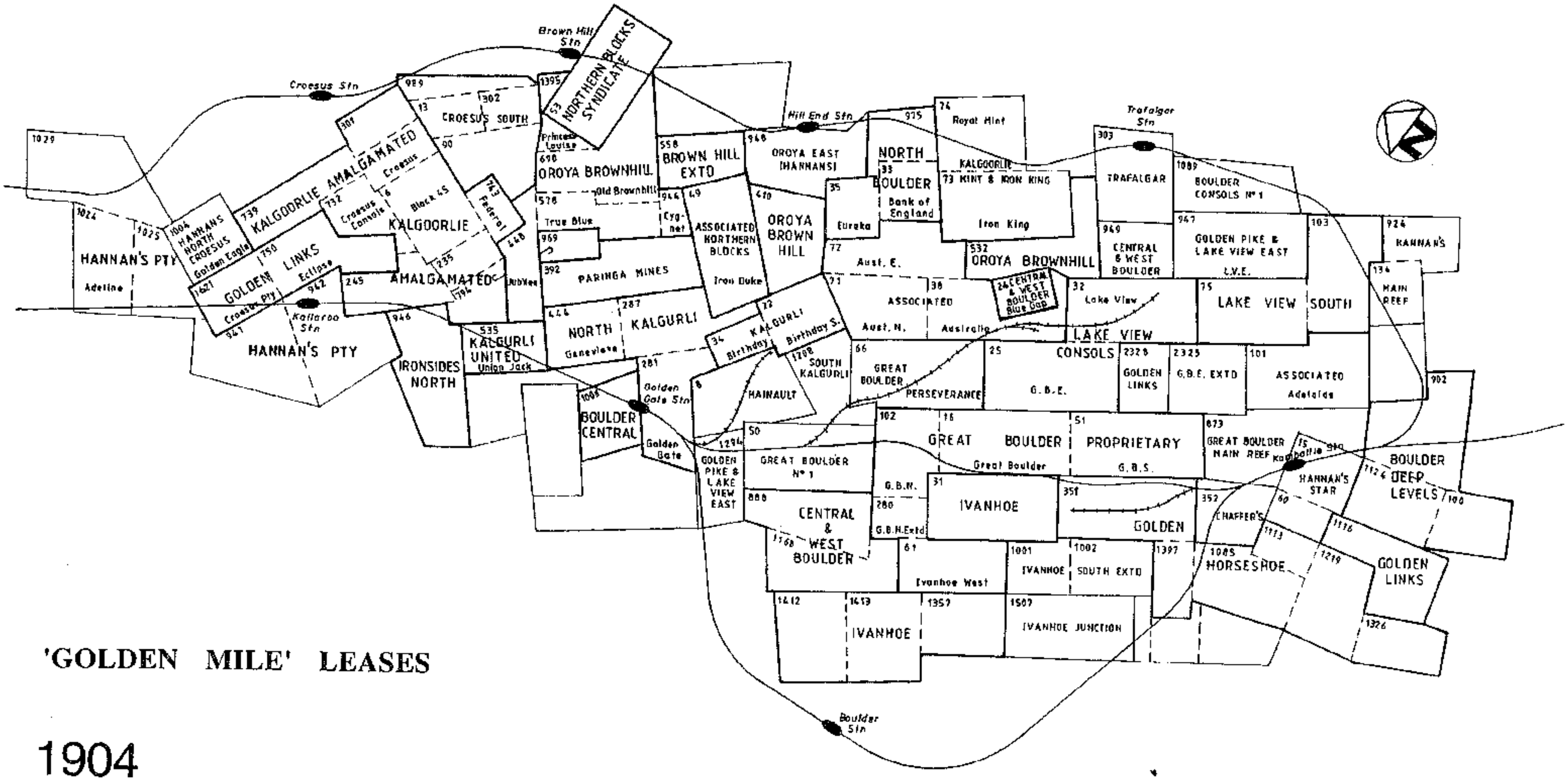
1 GOLD PRODUCTION IN WESTERN AUSTRALIA TO 1930



2 GOLD & MINERAL FIELDS



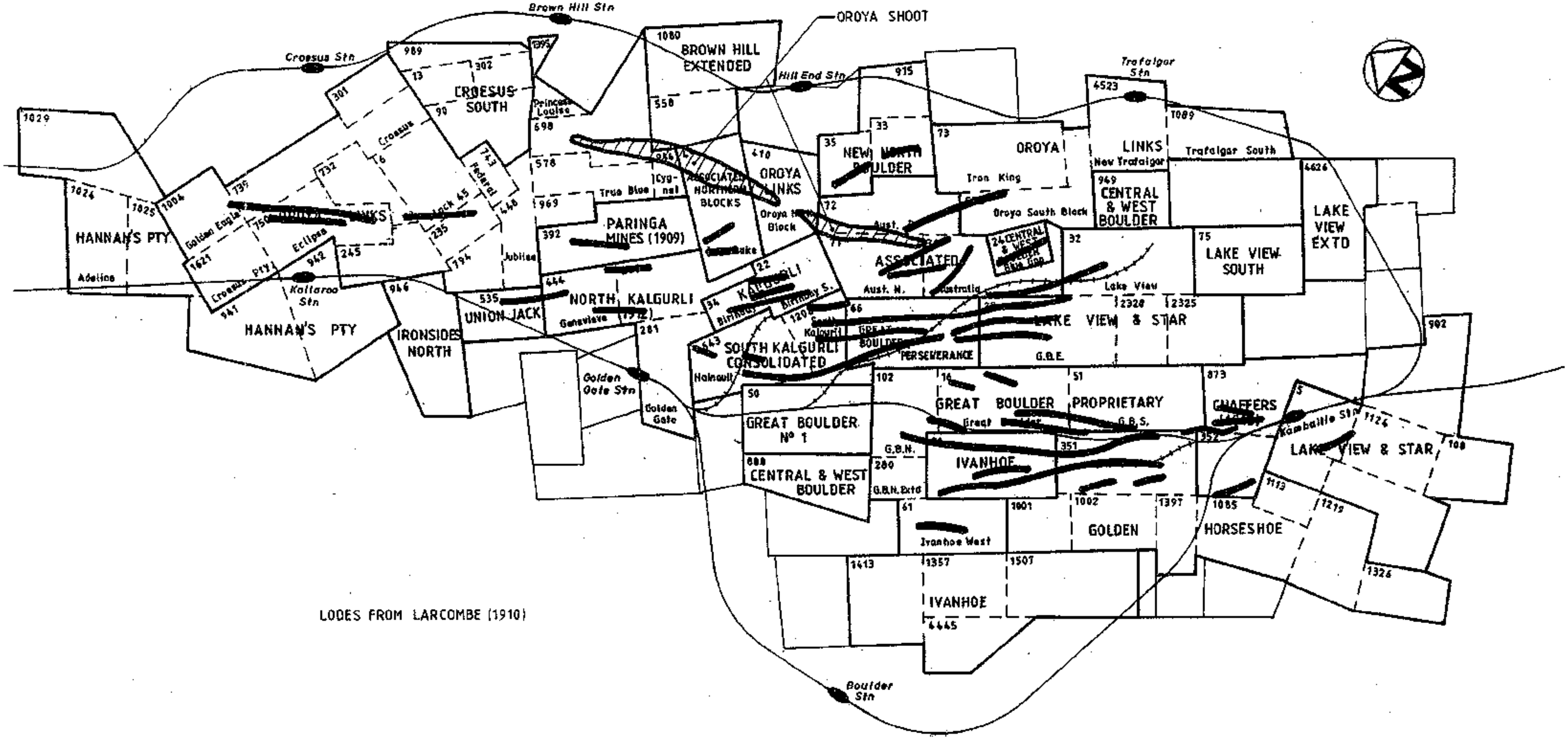
EASTERN GOLDFIELDS



'GOLDEN MILE' LEASES

1904

1.4



GOLDEN MILE LEASES (1913) AND TREND OF LODES FIG. 6